NTSB National Transportation Safety Board

Challenges of Increasing Automation in the Cockpit

Presentation to:

Georgia Tech School of Aerospace Engineering

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NTSB 101

- **Independent agency, investigate transportation accidents, all modes**
- **Determine probable cause(s) and make recommendations to prevent recurrences**
- **Single focus is *SAFETY***
- **Primary product: Safety recommendations**
  - **Acceptance rate > 80%**

The Challenges

- **Automation is becoming more complex**
  - **So the operators, and maybe even the designers, may not fully understand it**

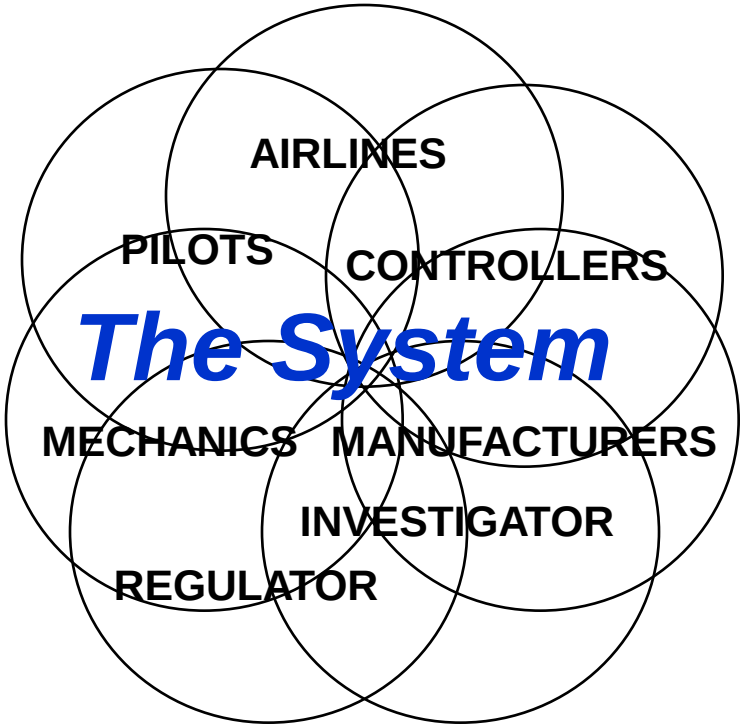
– and –

- **Automation is becoming more reliable**
  - **So the likelihood that the operators would have experienced any given failure, even in training, is very small**

Increasing Complexity

- **More System *Interdependencies***
  - – Large, complex, interactive system
  - – Often tightly coupled
  - – Hi-tech components
  - – Continuous innovation
  - – Ongoing evolution

- **Safety Issues Are More Likely to Involve *Interactions Between Parts of the System***



Effects of Increasing Complexity:

More "Human Error" Because

- System More Likely to be Error Prone
- Operators More Likely to Encounter Unanticipated Situations
- Operators More Likely to Encounter Situations in Which "By the Book" May Not Be Optimal ("workarounds")

The Result:

Front-Line Staff Who Are

- **Highly Trained**
- **Competent**
- **Experienced,**
- **Trying to Do the Right Thing, and**
- **Proud of Doing It Well**

. . . Yet They Still Commit

Inadvertent
Human Errors

The Solution: System Think

Understanding how a change in one subsystem of a complex system may affect other subsystems within that system

"System Think" via Collaboration

Bringing all parts of a complex system together to

- **Identify potential issues**
- ***PRIORITIZE* the issues**
- **Develop solutions for the prioritized issues**
- **Evaluate whether the solutions are**
  - **Accomplishing the desired result, and**
  - **Not creating unintended consequences**

Objectives:

Make the System

(a) Less Error Prone

and

(b) More Error Tolerant

System Think at the Aircraft Level

Aircraft manufacturers are increasingly seeking input, from the earliest phases of the design process, from

- ***Pilots*** **(*User* Friendly)**
- ***Mechanics*** **(*Maintenance* Friendly)**
- ***Air Traffic Services*** **(*System* Friendly)**

Increasing Reliability

- **Failures are so rare that the likelihood that the operators have seen a particular failure, even in training, is very small**
- **Solution:**
  - **Train operators re *specific failures?***
  - **Train re *how the system works,* hope the operators will comprehend it enough to figure out a specific failure in the moment?**

Examples of Unintended Consequences

Unanticipated:

- **Machine responses**
- **Human actions**
- **Human-machine interactions**

Unexpected Machine Responses, 2009

- **Turkish Airlines Flight 1951**
- **Washington Metro**
- **Air France Flight 447**

Turkish Airlines Flight 1951

- **The Conditions**
  - Malfunctioning left radar altimeter
  - Pilots responded by selecting right side autopilot
  - Aircraft vectored above glideslope
  - Autothrust commanded throttles to idle
  - Unknown to pilots, right autopilot using left radar altimeter
  - Pilot unsuccessfully attempted go-around

- **Queries:**
  - Should autopilot default to same side altimeter?
  - Tell pilots source of information, let them select?

Metro, Washington DC

- **The Conditions**
  - Electronic collision prevention
  - Parasitic electronic oscillation
  - Stopped (struck) train became electronically invisible
  - Following (striking) train accelerated
  - Stopped train was on curve

- **Queries:**
  - Train “disappearance” warning in dispatch center?
  - Train “disappearance” warning in following trains?
- **One Lesson Learned:**
  - Over-warning may be worse than *no* warning

Air France Flight 447

- **The Conditions**
  - Cruise, autopilot engaged
  - Night, in clouds, turbulence, coffin corner
  - Ice blocked pitot tubes
  - Autopilot became inoperative without airspeed
  - Alpha protections disabled
  - Pilots' responses inappropriate
- **Queries**
  - Pilots able to identify loss of airspeed info as a cause?
  - Pilot training re loss of airspeed information in cruise?
  - Pilot training re manual flying at cruise altitude?

Unexpected Human Actions

- **Chatsworth Rail Collision, 2008**
- **Minneapolis Overflight, 2009**
- **Duck Overrun, 2010**

Train Collision, Chatsworth, CA

- **Engineer of Commuter Train Texting**
- **Previously Warned Re Texting**
- **Passed Red (Stop) Signal**
- **Collided With Oncoming Freight Train**
- **NTSB Recommended In-Cab Camera**

Minneapolis Overflight

- **Controllers Lost Radio Contact With Airliner**
- **Airliner Still on Radar**
- **Overflew Destination**
- **Pilots Alerted by Flight Attendants**
- **Pilots on Laptops???**

“Duck” Overrun, Philadelphia

- **Duck Engine Overheated**
- **Duck Stopped, Anchored in Ship Channel**
- **Barge/Tug Operator on Cellphone**
- **Barge Empty, High in Water**
- **Barge/Tug Operator Not on Top Deck**
- **Radio Warnings Unanswered**

Human-Machine Interactions

- **Strasbourg, France, 1992**
- **Cali, Columbia, 1996**
- **Hudson River, 2009**

Autopilot Selection Error

- **Strasbourg, France, 1992**
- **Risk Factors**
  - *Night, mountainous terrain*
  - *No ground radar*
  - *No ground-based glideslope guidance*
  - *No airborne terrain alerting equipment*
- **Very Sophisticated Autopilot**
- **Autopilot Mode Ambiguity**

Autopilot Mode Ambiguity

- **"3.2" in the window, *with a decimal*, means:**
  - **Descend at a *3.2 degree angle (about 700 fpm at 140 knots)***
- **"32" in the window, *without a decimal*, means:**
  - **Descend at *3200 fpm***
- **Clue: Quick Changes in Autopilot Mode Frequently Signal a Problem**
  - ***Flight data recorder readout program could have helped safety experts uncover this problem***

Another Interaction Failure

- **1995 – Cali, Colombia**
- **Risk Factors**
  - ***Night***
  - ***Airport in deep valley***
  - ***No ground radar***
  - ***Airborne terrain alerting limited to "look-down"***
  - ***Last minute change in approach***
    - ***More rapid descent (throttles idle, spoilers)***
    - ***Hurried reprogramming***
- **Navigation Radio Ambiguity**
- **Spoilers Do Not Retract With Power**

Recommended Remedies Include:

- **Operational**
  - ***Caution re last minute changes to the approach!!***
- **Aircraft/Avionics**
  - **Enhanced ground proximity warning system**
  - **Spoilers that retract with max power**
  - **Require confirmation of non-obvious changes**
  - **Unused or passed waypoints remain in view**
- **Infrastructure**
  - **Three-letter navigational radio identifiers**
  - **Ground-based radar**
  - **Improved reporting of, and acting upon, safety issues**

Note: All but one of these eight remedies address system issues

Landing on the Hudson

- **Ingestion of birds destroyed both engines just after takeoff**
- **No training or checklist, but previous glider experience**
- **Pilots unaware of phugoid damping in software**

- **Phugoid damping did not permit full nose-up alpha**
- **Higher vertical impact velocity due to inability to obtain full nose-up alpha**

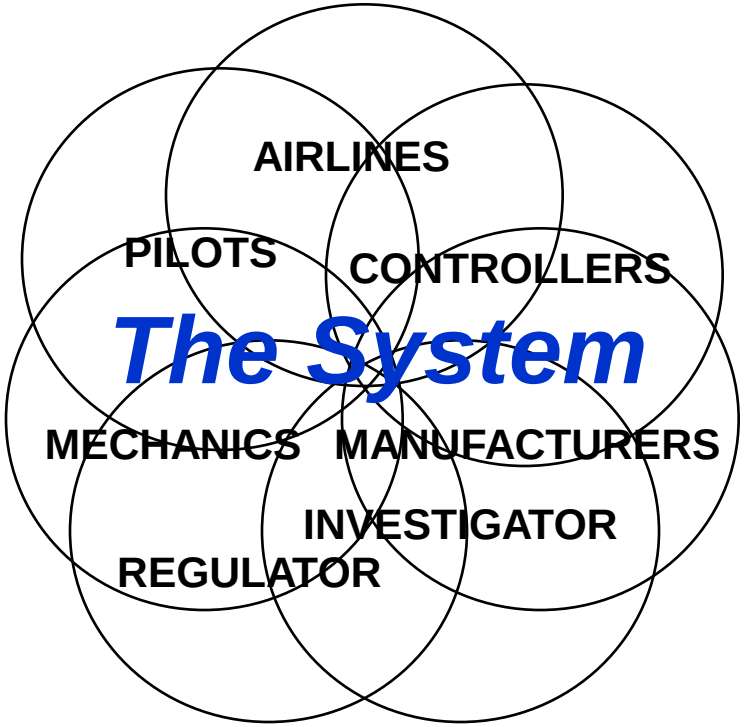
Big Picture: Collaboration at the Aviation System Level?

- **Mid-1990's, U.S. fatal commercial accident rate, although commendably low, had stopped declining**
- **Volume of commercial flying was projected to double within 15-20 years**
- **Simple arithmetic: Doubling volume x flat rate = *doubling of fatal accidents***
- **Major problem because public pays attention to the *number* of fatal accidents, not the *rate***

Commercial Aviation Safety Team (CAST)

Engage *All* Participants In Identifying Problems and Developing and Evaluating Remedies

- **Airlines**
- **Manufacturers**
- **Air Traffic Organizations**
- **Labor**
  - ***Pilots***
  - ***Mechanics***
  - ***Air traffic controllers***
- **Regulator(s)**



The Result

65% Decrease in Fatal Accident Rate, 1997 - 2007

largely because of

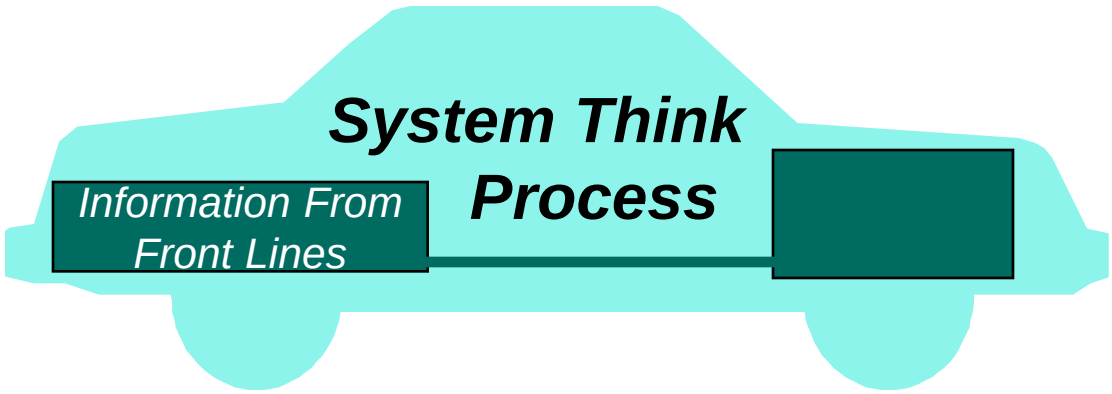
System Think

fueled by

Proactive Safety Information Programs

P.S. Aviation was already considered *VERY SAFE* in 1997!!

Icing on the Cake: A Win-Win



Improved
Safety

- AND -

Improved
Productivity

P.S. Collaboration also reduced the likelihood of unintended consequences!

Contravene Conventional Wisdom??

- Conventional Wisdom:

Changes that improve safety usually *also reduce productivity*

- Lesson Learned from the CAST process:

Safety can be improved in a way that also results in *immediate productivity improvements*

The Health Care Industry

To Err Is Human:

Building a Safer Health System

"The focus must shift from blaming individuals for past errors to a focus on preventing future errors by designing safety into the system."

Institute of Medicine, Committee on Quality of Health Care in America, 1999

Aviation Win-Win:
Transferable to Other Industries?

- Other Transportation Modes
- Nuclear Power
- Chemical Manufacturing
- Petroleum Refining
- Financial Industries
- Healthcare
- Others

Thank You!!!

Questions?